

Multi-component models for disk galaxies.

A test case on NGC 5866

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Abstract.

We present an application of a new set of detailed, self-consistent, dynamical models for disc galaxies. We start from the hypothesis that each galaxy can be decomposed in a bulge, following the $r^{1/4}$ law, and a disc with an exponential projected density profile; and that the isodensity surfaces of each component can be represented by similar concentric spheroids. After taking into account both the asymmetric drift effects and the integration along the line of sight, we produce the rotational velocity and velocity dispersion profile, **and** the approximate shape of the line of sight velocity distributions for the stars as parameterized by the h_3 and h_4 coefficients of the Gauss-Hermite expansion of the line profile.

Photometric and kinematical data have been taken from the literature for the test case of the S0 galaxy NGC 5866, for which detailed stellar kinematical data are available at different positions across the galaxy. Apart from the very inner, dust-obscured regions of the galaxy, where observational effects are likely to be dominant, the model successfully reproduce the whole set of dynamical data available as well as giving a good fit to the photometry. The galaxy is shown to have an isotropic velocity dispersion tensor, thus giving a hint on a dissipational formation process.

1. Introduction

The study of S0 galaxies could provide the link between the dynamically hot, pressure-supported elliptical galaxies, sustained by the anisotropy of their velocity dispersion tensor, and the colder, isotropic and rotationally-supported spiral galaxies.

These dynamical differences are likely to be derived from different formation histories: under very simple assumptions, we expect the isotropic structures to derive from the dissipational collapse of a spherical distribution (or from the mergers of gas-rich galaxies), and the anisotropic ones to be the result of dissipationless processes such as mergers of gas-poor parent galaxies.

S0 galaxies shows a very wide range of dynamical behaviors, suggesting that they might form a somewhat “mixed” class at this regard. In order to investigate the different behaviors of the star kinematics in these galaxies we developed a self-consistent, multi-component dynamical model, that could be used to derive simultaneously both the mass distribution and the mean kinematical anisotropy in S0 galaxies.



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Then we looked for a test case, taking data from the literature to check the model. We choosed the S0 galaxy NGC 5866, mainly because it is an object with good photometrical and dynamical data available, and because velocity and velocity dispersion profiles are present in the literature also out of the major axis. These latter profiles are essential to find the anisotropy of the velocity dispersion tensor of the galaxy.

2. The hypothesis of the model

The galaxy is supposed to be composed by the superposition of different components. For each component, assume:

- There is axial symmetry, so that no bars, warps or misalignments between the different components are allowed;
- The isodensity surfaces are similar concentric spheroids;
- The density profile follows a simple $r^{1/4}$ or exponential law;
- The velocity distribution is locally Gaussian;
- The anisotropy parameter β is constant through the galaxy;
- The galaxy is rotating around its z -axis with velocity $V(R, Z)$, consistent with the self-gravity hypothesis;
- Each component has a constant M/L ratio;
- Since we are dealing with the inner kinematical properties of the galaxies, we deliberately discard any dark matter contribution to the overall potential, to limit the number of free parameters.

We separately fit the major and minor axis profile of the photometry; the usual ellipse fitting to the 2-dimensional photometric profile is shown to give worst results here, because in the special case of S0s the shape of the composite (bulge + disc) isophotes is far from being ellipsoidal.

Different mass and potential models are then produced with different M/L ratios, all compatible with the observed photometric data.

For each model, we integrate the Jeans equation under the hypothesis sketched above, obtaining a self-consistent model of the rotational velocity and velocity dispersion of the different components, including the asymmetric drift effects.

Assuming that each component has a Gaussian velocity distribution, we calculate the momenta of the global velocity distribution and

integrate them along the line-of-sight. The stellar line-of-sight velocity distribution parameters are obtained in the framework of the usual Gauss-Hermite expansion series (??)

Since we do not actually integrate along the line-of-sight the whole line shape, but only the momenta of the velocity distribution, the V , σ , h_3 and h_4 parameters are obtained by means of a first order approximation (as described in ? (?))

3. Results and discussion

The model has been checked on the following dataset, available in the literature for the S0 galaxy NGC 5866:

- velocity dispersion and rotational velocity profiles over 7 different axis across the galaxy (??), as shown in Fig. 1;
- h_3 and h_4 profiles for 5 of these axis (not reproduced here for shortness, ? (?));
- photometric profiles along the major and minor axis (?).

Table I. Parameters from the Dynamical Model for NGC 5866. The labels b and d refers to the bulge and disk components.

scale radius		axial ratio		Luminosity		Mass [$10^{10} M_\odot$]		i
r_b	r_d	$(b/a)_b$	$(b/a)_d$	L_b	L_d	M_b	M_d	
35''	15''	0.8	0.15	62 %	38 %	5.58	1.72	71°

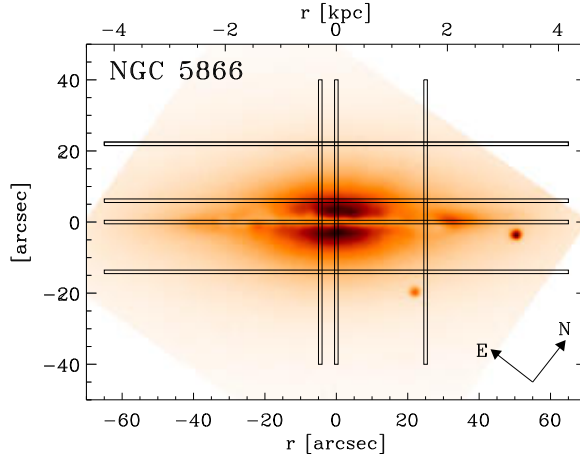


Figure 1. An image of the galaxy NGC 5866. The approximate position and extension of the kinematical profiles (??) are shown superimposed on the multi-color image of the galaxy (?).

The presence of a dust lane, which prevent us from looking through the entire line-of-sight- of the galaxy, has been taken into account by:

- Removing the inner 5 arcsec points from the photometric R-band profile (where the sudden drop of the surface brightness profile, in Fig. 2);
- Removing from the fit the inner rotational velocities, heavily affected by the dust (corresponding to the dashed lines models in Fig. 3).

Little effect is expected on the velocity dispersion.

The best-fit model is a two-component (bulge+disk) model whose parameters are shown in Tab. I. The agreement between the model and the data is good for both the velocity dispersion profiles and the rotational velocities everywhere, *except in the inner regions of the major axis*. This discrepancy, together with the somewhat smaller discrepancy in the minor axis rotational profile near the nucleus, can be easily ascribed to the presence of the dust lane.

Due to the large uncertainties in the inner structures, we find that there are several different models that fits the data. However, the differences are mainly restricted to the inner regions of the galaxy, while

the global parameters of the model are fairly constrained. The model we are showing in Figg. 3–5 has a central spherical component that accounts for the big asymmetric drift noticed in the stellar kinematics, and an isotropic velocity dispersion tensor.

On the other hand, no model with any significant amount of anisotropy has been able to improve the fit between the model and the data.

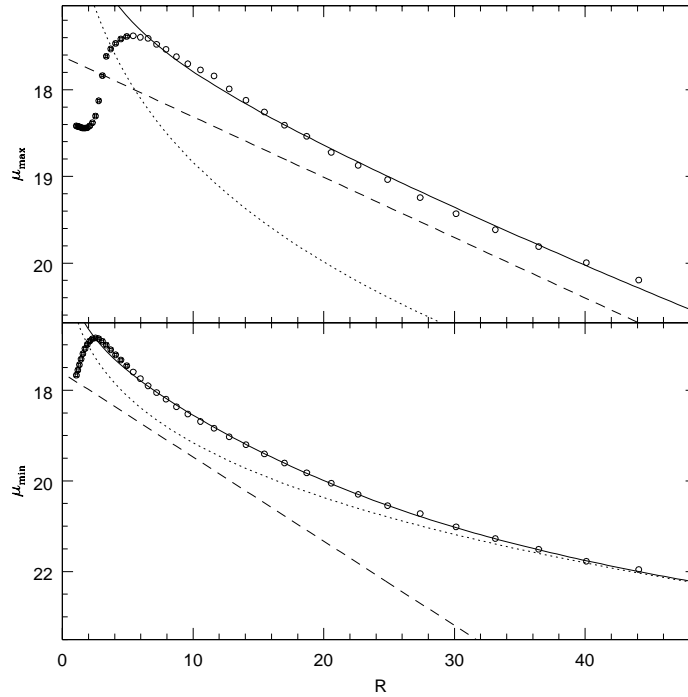


Figure 2. Major and minor axis R-band photometric profiles, compared with the two components best-fit model. The dashed lines shown the contribution of the bulge and disk to the total surface brightness profiles (solid line). The crossed circle represent the points which have been excluded from the automatic fit due to the effect of the absorption of the dust lane.

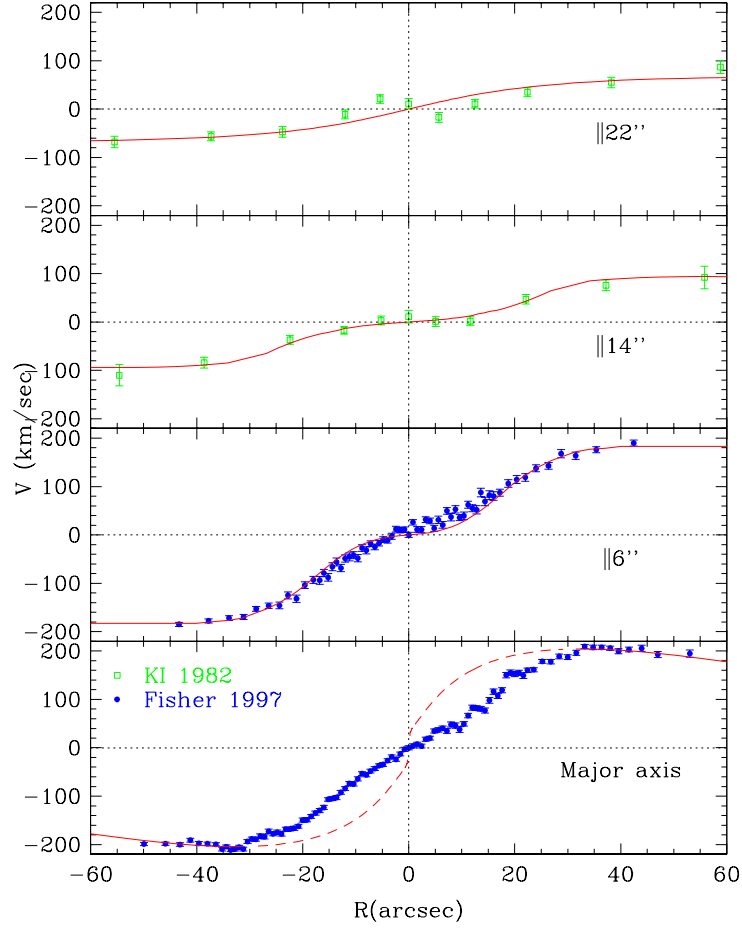


Figure 3. Rotational velocity profile of stars and gas as compared to the model of the stellar kinematics, for the axis parallel to the major axis. The dashed line on the model correspond to the region obscured by the dust lane.

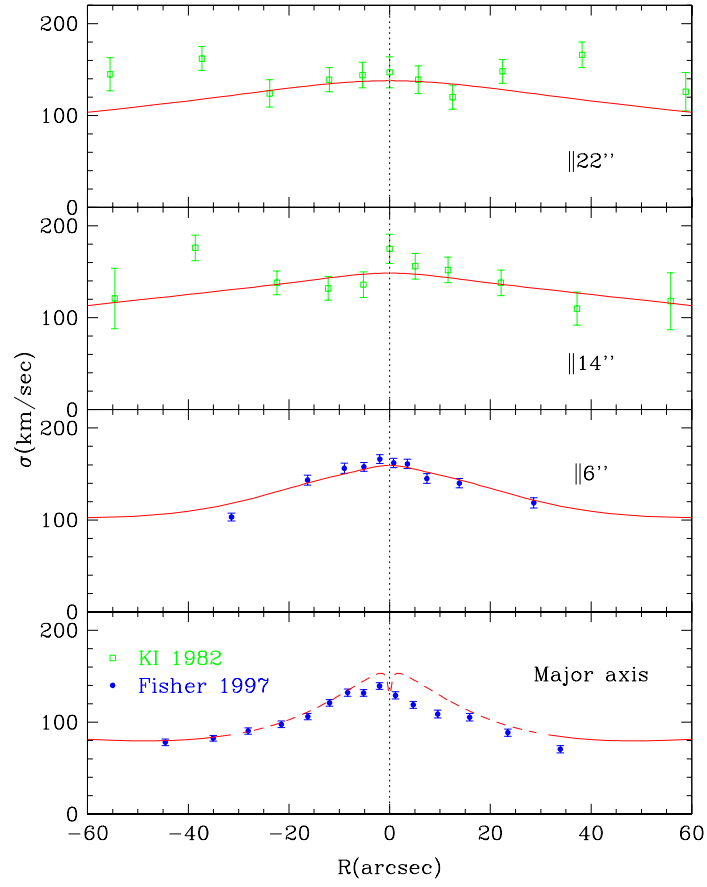


Figure 4. Same as Fig. 3, but for the velocity dispersion profiles.

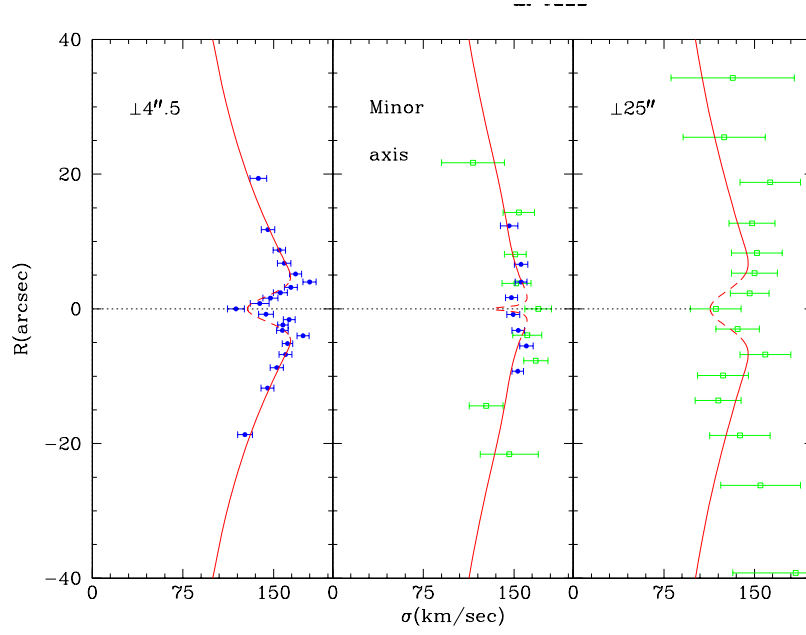


Figure 5. Same as in Fig. 4, but for the perpendicular cut shown in Fig. 1.

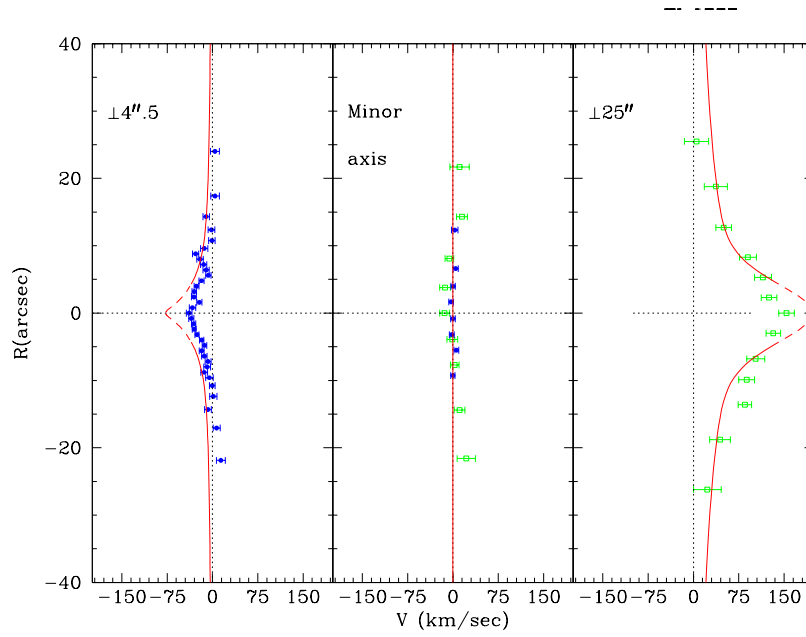


Figure 6. Same as in Fig. 3, but for the perpendicular cut shown in Fig. 1.